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From science teacher to 'teacher scientist': Exploring the experiences of research-active science teachers in the UK

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Abstract

We explore the professional identities of UK-based secondary science teachers who actively participated in science research for at least six months. The study uses thematic analysis to analyse semi-structured interviews with seventeen participants across England and Scotland, from a variety of educational/socio-economic contexts. We found that through participation in research projects, teachers develop a multi-faceted sense of professional identity that includes the roles of teacher, scientist/researcher, mentor and coach. Teachers who are research-active develop complex professional networks that have a positive impact upon their sense of professional worth and self-belief. Through participation in research, teachers identified as both science teachers and scientists and this has been encapsulated in this research as a transition in professional identity to 'teacher scientist'. The key enabling factor in identification as a 'teacher scientist' is a teacher's positive interaction with scientists/researchers. Teachers are motivated to participate in research projects in response to the enthusiasm of their students and a desire for students to contribute to research that could provide solutions to real-world challenges. This understanding of the capacity of science teachers to become 'teacher scientists', and recognising teachers' altruistic motivations, could contribute to teacher retention and recruitment strategies that are less focused on financial incentives.

Keywords: science teacher, research in science, professional identity, social identity approaches, teacher scientist

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Introduction

The Institute for Research in Schools (IRIS) is a UK-based charity that launched in March 2016 to develop an approach to school education where research is a key element of STEM (science, technology, engineering and mathematics) learning that offers opportunities for students to work on genuine problems (Parker, Fox & Rushton, 2018). This approach resonates with the concept of what is sometimes termed 'authentic learning'. This term is used with a range of meanings but in the context of school science education it has been argued that practical work "is more 'authentic' than much of what goes on in school laboratories when it helps demonstrate or it replicates the sort of work that scientists frequently undertake in modern science, or if it is perceived as having relevance to solving real-life problems" (Braund & Reiss, 2006, p. 1378), as when students and teachers are contributing to knowledge by focusing on what is not already known, as part of an inquiry that has value beyond the classroom (Newmann, Marks & Gamoran, 1996; Lombardi, 2007; Bennett et al., 2018). Students and teachers collaborate with active researchers based in universities and industry and IRIS supports schools in building research networks and provides access to data and experimental equipment. This is a social constructivist approach to learning, where students are supported by their peers, teachers and other collaborators, to develop both their understanding of science and to further science itself (Parker et al., 2018). The role of the school teacher is to encourage, support and facilitate their students' participation.

At the outset, IRIS was not established to provide professional development opportunities for teachers of science (which has been extensively done in England through a range of

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providers, e.g. the National STEM Learning Centre). However, one of the knock-on effects of IRIS' approach to science education has been to enable science teachers to engage with STEM research. Support and guidance for teachers is provided by IRIS staff and research scientists associated with individual projects through a combination of webinars, training videos, written materials, email groups, school visits and a mentoring system where more experienced teachers support other schools in their geographical area. This is not a pre-designed professional development programme, more a framework to provide teachers across a large geographical area with effective and efficient support.

Informal conversations between IRIS staff and teachers revealed that many teachers viewed this experience positively and valued the opportunity to extend their own subject knowledge and research skills alongside those of their students. These conversations provided the starting point for this current study so that the experiences of research-active science teachers, and their professional identities, could be better understood.

One project, *Genome Decoders*, provides a representative example of the types of engagement and collaborations between school students, teachers and research scientist partners across the wider group of projects experienced by teachers in this study. From 2017-2019, teachers and students from over sixty schools, supported by scientists at the Parasite Genomics team at the Wellcome Sanger Institute and the WormBase team at EMBL-EBI (European Molecular Biology Laboratory-European Bioinformatics Institute), were trained to annotate the genome of the human whipworm (*Trichuris trichiura*) (Rushton & Parker, 2019). The whipworm is a parasite that causes trichuriasis (whipworm infection), a neglected

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tropical disease that affects over 500 million people globally, mainly children living in the poorest parts of the tropics, including Africa, Asia and South America (Barda, Keiser & Albonico, 2015). Annotating the genome enables the identification of the genes that code for proteins and which are important during infection and the manifestations of the disease, which can lead to identifying a treatment and or cure. To annotate a gene, students interpreted the sequencing data generated by Illumina and Pacific Biosciences sequencing platforms to identify regions of the genome containing genes, and to annotate transcript structures in terms of their constituent exons and introns. To enable school students to contribute to the annotation of the genome, a framework based around the web-based genome annotation editing tool Apollo (Lee et al., 2013) was designed. An important aspect of the framework was detailed tagging and tracking of annotations, which enabled work to be allocated, checked and reported on at the level of individual students and this information was shared with their teachers through the web-based platform. Genome annotation using Apollo or similar tools is usually performed by postgraduate and post-doctoral researchers and professional curators and this project required students and teachers to understand and apply complex language and concepts related to genome research. In these ways, students, teachers and technicians worked collaboratively to contribute to the annotation project. Research undertaken by students, teachers and scientists in physics-based projects has resulted in published research with student co-authors (Furnell, Shenoy, Fox & Hatfield, 2018; Whyntie & Harrison, 2015).

Social identity approaches and education

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Education is a collaborative process that involves groups of people and yet social identity approaches have only recently been used for education research (Mavor, Platow & Bizumic, 2017). Social identity approaches combine the theories of social identity (Tajfel & Turner, 1979) and self-categorisation (Turner, Hogg, Oakes, Reicher & Wetherall, 1987) which together are referred to as 'the social identity approach' (Haslam, Reicher & Platow, 2011). These approaches suggest that a person's sense of self is determined by their social context, the groups to which they belong and identify with, and that people seek to develop and maintain a positive view of themselves by comparing themselves and their group memberships in a more positive light than their alternative 'outgroups' (Tajfel & Turner, 1979; Ellemers & Haslam, 2012). Social identity theory suggests how groups form (Turner, 1982) whereas self-categorisation theory suggests when groups form and recognises that this is part of a context-sensitive, self-categorisation process (Turner, 1982; Oakes, Haslam & Turner, 1994).

In a review of current research, Haslam (2017) identifies that five 'I's that have significance for social identity and education; *Identification*, *Ideation*, *Interaction*, *Influence* and *Ideology*. *Identification* is based upon the idea that group membership shapes an individual's behaviour to the extent that their social identity derived from this group membership is incorporated into their sense of self. Research considering identification and teachers has shown that levels of identification are good predictors of engagement (Christ, van Dick, Wagner & Stellmacher, 2003), job satisfaction (van Dick & Wagner, 2001) and self-reported physical (van Dick & Wagner, 2002) and psychological (van Dick & Wagner, 2001) health and well-being. *Ideation* or *what* people identify with is as important as mutual identification. What students

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are told about the groups they identify with shapes students' behaviour in both school (Mutjaba & Reiss, 2013; Boucher & Murphy, 2017) and university (Cruwys et al., 2017) settings. Studies considering the role of ideation in shaping the behaviour and performance of teachers have not featured thus far in the literature and this research seeks to address that gap, specifically considering whether science teachers identify themselves as scientists and researchers as well as teachers of science. *Interaction* is what develops and galvanises social identities (Haslam, 2017) and this interaction has the capacity to shape the extent to which individuals feel part of the group and therefore can increase or limit their academic and intellectual performance (Reynolds et al., 2017). As with ideation, studies that specifically explore the ways in which interaction shapes teachers' experiences and sense of self have not formed part of the literature and this research explores how teachers interact with different groups as part of their experience of research. *Influence*, Haslam (2017) suggests, is what makes identification, ideation and interaction possible; it is the extent to which leaders can shape the attitudes, intentions and behaviour of followers. Levels of influence are determined by how much followers socially identify with their leader. *Ideology* pervades education, and multiple aspects of the educational landscape (e.g. class, political views, gender, race, faith) provide teachers with the context for identification, ideation and interaction. (Haslam, 2017).

A current movement in education is to empower teachers and increase their levels of professionalism through engagement with research (Peacock, 2018). Although much professional development for teachers is focused on pedagogical research, the involvement of teachers in subject-specific research is generally seen as a positive contribution to their subject knowledge, development of skills and job satisfaction (Parker et al., 2018). Rich,

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Mavor and Webb (2017) underline the important role that social identity approaches can have when seeking to understand the development of teachers' professional identities. Socially constituted and negotiated aspects of teachers' identities are core within our complex understanding of teachers' identity – something that moves from the singular, fixed and constant to that which is multiple, fluid and dynamic (Miller Marsh, 2002; Rich et al., 2017). Social identity approaches enable an exploration of how group-level interactions shape teachers' sense of what it is to be a teacher and how they make sense of themselves as particular kinds of teachers at different stages in their careers (Rich et al., 2017).

Teacher identity approaches from educational research

Much research exploring the formation and development of teacher identity has focused on transition phases: students training to be teachers, newly qualified and early career teachers (Walkington, 2005; Beauchamp & Thomas, 2009; Mockler, 2011). Beauchamp and Thomas (2009) suggest that understandings of teacher identity should more frequently inform teacher education and continuing professional development. Key areas relevant to this study include definitions of teacher identity and its dynamic nature, the role of narrative, the self and agency in the formation of teacher identity.

Teaching secondary science in the UK

In 2017, 80% of UK-based teachers surveyed reported that they were considering leaving the profession, an increase from 50% in 2014 (Adams, 2018), and the percentage of secondary teachers of working age who have left teaching rose from 9% to 11% between 2010 and 2015 (Worth, De Lazzari & Hillary, 2017). There is a link between high teacher turnover and lower

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student attainment in both the UK (Telhaj, Gibbons & Scrutinio, 2017) and the USA (Ronfeldt, Loeb & Wyckoff, 2012). The loss of experienced teaching professionals in England is keenly felt in science teaching, with English schools facing a severe shortage of science teachers (Migration Advisory Committee, 2016). Research suggests that science teachers in secondary schools are 26% more likely than secondary teacher in other subjects to leave their school within five years (Allen & Sims, 2017). Newly qualified science teachers are 35% more likely to leave their first school within five years than are newly qualified teachers in other subjects and if these science NQTs have a physics or engineering degree they are 87% more likely to leave (Allen & Simms, 2017).

An evaluation of the impact of high-quality, subject-specific continuing professional development courses led by The National STEM Learning Network suggests that teachers are 160% more likely to stay within the profession if they regularly access this type of continuing professional development, improving teacher retention and student attainment (Allen & Simms, 2017). The research that science teachers participate in when working with IRIS is not formally recognised as continuing professional development. However, the school leaders who support science teachers who work with IRIS research projects recognise such work as part of performance management review targets for teachers. School senior leaders acknowledge that teachers who are research-active bring many benefits to teacher professional development and student attainment and progression. This current study may contribute to understandings of science teacher recruitment and retention in the UK.

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At the same time, we neither see the practices we advocate in this article as a panacea to arrest teacher turnover nor do we believe that *every* science teacher needs to be research-active. No doubt there are and will continue to be many excellent science teachers who are not what we call below 'teacher scientists' and who have no particular wish to be such, just as there are many excellent art teachers who are neither artists nor teacher artists. Our contention is, rather, that there are some science teachers for whom engaging in research will have substantial benefits for them and for their students.

Based upon the literature, the following main research questions were identified:

1. What are the experiences of UK-based secondary school science teachers who are research-active?
2. What are the professional identities of research-active science teachers?
3. What are the key challenges and opportunities that science teachers experience when they are research-active?

Methods

Participants

Seventeen participants were recruited for the study from the IRIS network of teachers. Eight are female and nine are male and all teach one or more science subjects (biology, chemistry and physics) at secondary school level (Table 1). All have been working on research projects with their students and with teachers and students from other schools for at least six months. All are working in schools that had registered with IRIS. Participants have diverse teaching experience, ranging from newly qualified teachers to those who had been teachings for over

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30 years (Table 1). Six participants have a PhD in a science subject and nine are currently in management roles, including subject leader and curriculum leader (Table 1).

[Table 1 near here]

Participants were drawn from a wide geographic range in England and Scotland, from Cornwall to Stirling, and schools included Academies, Local Authority comprehensive and grammar schools and fee-paying independent schools (Table 2). This ensured that the study incorporated the experiences of teachers from a range of educational contexts with different ideologies. The ethnicity of participants was not requested or disclosed.

[Table 2 near here]

Data collection procedure and ethical approval

Ethical approval for this study was received on 28th November 2017 from the Ethics Committee of Canterbury Christ Church University (Ref: 17/SAS/22C). Participants were recruited during December 2017 – February 2018 through a combination of an email request for participants, suggestions of participants from IRIS staff and from teachers who had a pre-existing professional relationship with the first author. An interview schedule was prepared with questions in three main sections: *background* information, including information about the participant's teaching role and research role; the *impact* of the research on the participant's experience of the subject taught; and the *experience* of teaching and their sense of self. Prior to the interview the participants were given a Participant Information Sheet and

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at the beginning of the interview they signed a consent form. Participants were told that they could withdraw their data at any point up until 1 June 2018. The interviews were conducted during visits to the participants' schools to ensure that they were in a comfortable, familiar environment and the interviews were at a time chosen by the participant, carried out during January – March 2018. The interviews were audio-recorded and transcribed shortly after each interview according to Braun and Clarke's (2006) guidelines for thematic analysis.

Results

The interview transcripts were analysed using the six phases of Thematic Analysis outlined in Braun and Clarke (2006; Braun, Clarke & Terry, 2012). Five superordinate themes emerged from the data, each with sub-ordinate themes, and were created from several initial codes (Clarke, Braun & Hayfield, 2015), as summarised in Table 3. We discuss in the subsequent Discussion section how these themes relate to the social identity framework we review above.

[Table 3 near here]

Analysis began from the premise that what participants say about their experience is a reflection of their reality and lived experience (Braun & Clarke, 2006; Braun et al., 2012). As such, the analysis used in this study employs an inductive, semantic approach that allows theory to emerge from the data. A semantic approach (focusing on the explicit meaning of participants' statements) rather than a latent approach (where the researcher interprets meaning that is not explicitly communicated by the participant) was chosen to code the data (Clarke, Braun & Hayfield, 2015). A semantic approach enables those undertaking the

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analysis to focus on experiential meanings, rather than possible social constructions of meaning that it might be believed participants could and/or should have intended. In reality, is not possible entirely to separate analysis from the research context (Clarke, Braun & Hayfield, 2015). In Phase 5, the identification and naming of themes, both descriptive (data used to illustrate themes) and interpretative (data used to understand latent meaning) analysis were used. Braun et al. (2012) demonstrated that these two approaches can be successfully combined.

Table 4 presents the number of references made in interviews per subordinate theme (so, totals are sometimes greater than the number of participants). Teachers discussed the theme 'Freedom to teach' most frequently number of teacher references: (n=97), compared to '(Re)Connection with science/research' (n=77), 'Collaboration' (n=74), 'Professional development' (n=70) and 'Student/societal development through research' (n=43).

[Insert Table 4 near here]

Superordinate theme A: Freedom to teach

When describing the experience of research as part of the weekly work of a teacher, 'freedom' was a word that was frequently used. Freedom was connected to the flexibility and variety of teaching methods and approaches, and freedom from the constraints of general workload and external examinations and curricula. One participant described in detail the freedom that research gave to the method of teaching, saying that when working on research projects with her students she was able to allow them the time needed to develop their ideas

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with minimal direction from her. She contrasted this with the teaching method required in classroom science when the large amount of content meant there was not enough time to allow students the freedom to make mistakes and learn from them in classroom experiments:

> My role with the students in the research project is that it is much less directed … with huge time pressures and curriculum content only increasing you are having to push them in the right direction, but with [research] … you are planning and analysing over a long time. (SG)

The intellectual freedom for students who engaged with research was found to be both a 'wonderful' opportunity and a challenge, and it was the teacher's role to help students negotiate this boundary successfully. Another participant described the role of the research day in protecting his time with his students and said that working in research prevented the other demands of teaching from absorbing all his energies:

> The freedom I get with this research day … it keeps you going, it stops the marking and workload from squeezing everything else out. The kids turn up and they want to do research and I can't say no! (CI)

Participants contrasted the 'dull' curriculum with the freedom of research and experimentation. Some participants acknowledged that this approach would not be one chosen by all science teachers:

> Well, this role doesn't suit everyone, but I think that part of being a scientist is about … just trying something, seeing if it works and if it doesn't try something else,

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> experiment, observe, report, evaluate, that is the scientific method really, and that doesn't suit everyone. (JT)

Together with this acknowledgement of professional freedom came the recognition of continued time constraints. Participants recognised that there were times of the year (March – June) and even whole year groups (Year 11, students aged 15-16 years) where there was no time for research activities as the focus was on external GCSE[1] examinations:

> There is so much pressure on students and teachers for great results at GCSE that it is almost impossible to get students the time they need to do this [research] in Years 10 and 11. They want to, they do it in Years 7 to 9 and then the pressure kicks in and then you hope you can get them back at Year 12 and 13. (CI)

In contrast to this understanding that students (particularly during Years 10 and 11) did not have control over their time, there was a recognition that it was possible for teachers to 'make time' if they wanted to incorporate research into part of their and their students' experience of teaching and learning science:

> To be honest, more teachers could do this [research] if they really put their mind to it. (GC)

Other participants also suggested that lack of time was the significant factor in limiting the amount of research both they and the students could do:

[1] General Certificate of Secondary Education examinations are taken by students at the end of Year 11, aged 15-16 years. GCSEs provide the curriculum for students during Year 10-11 (14-16 years of age), with some students beginning to study for GCSEs in Year 9 (13-14 years).

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> The greatest challenge with research is time; I wish I had more time to devote to Genomics as a teacher … I would also like to spend more time supporting the students and I wish they had more time to devote to it, but they are spending time on a Friday after school so they really are committed, they just don't have any more time. (JM)

This quotation comes from a teacher working with students in Year 12, so some teachers and students work increasingly hard to balance their workloads to incorporate research into their experience of science at school. Some participants saw their ability to take on the research aspect of their professional life as a direct consequence of having a leadership role in school, and/or because they were the only subject specialist in school, so were able to take decisions about curriculum delivery that meant they could incorporate research as part of classroom teaching rather than simply as an extra-curricular club or activity.

Freedom and time available are linked themes since a participant who feels free to do research will feel they have more time available to undertake research compared to a teacher who feels more constrained. The participants who identified with a sense of freedom had been teaching for at least 10 years, and some had positions of responsibility; this may have contributed to their increased sense of freedom to pursue research, compared to those teachers who were in earlier phases of their teaching career.

Superordinate theme B: (Re)Connection with science/research

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Participants talked about their reconnection to their science subject, to research and, for some, to their sense of being a scientist. This movement through the spaces of subject teacher, researcher and scientist was different for those participants who had a PhD and had experienced research at doctoral and post-doctoral level and for those who had not. An apparent difference was one of connection and *re*connection with the role as a scientist, with those who had not (yet) had the opportunity to undertake a PhD identifying this experience of research as enabling them to connect with that sense of being a scientist that they had developed as an undergraduate student but had not carried on: 'This project has connected me with my roots as a scientist' (JM). SG reflects that her experience of research has fundamentally reconnected her with research and with her identity as a scientist:

> After this experience of research, I would be far more likely to describe myself as a scientist … which is in some ways surprising as I have taught science to students for over 20 years, but it is that connection with current research and academics and being part of the understanding of new science that I think has made me feel far more likely to describe myself as a scientist. (SG)

For some of those participants who had undertaken research at doctoral level and beyond, research with their students provided them with a chance to draw on that experience:

> Working in research with students has allowed me to develop a relationship with them at a different level because I am able to share with them my past world as a research scientist and just seeing them tantalised by that, it gives me a lot of pleasure. (NR)

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One participant who had completed a Master's degree in education but had not been involved in science research since his undergraduate degree found that the process of research, particularly working to discover new ideas and theories in science, invigorated his experience of teaching science:

> I have found myself, it enthuses you, being engaged in research, asking questions again, being alongside people in a journey of genuine discovery and challenge, finding ways around problems. (CI)

Other participants suggested that they reconnected with the subject that they taught and with science in general:

> This project, this experience has reminded me how much I enjoy science, both studying it as well as teaching it, it has brought my own sense of inquiry to the forefront of my mind which I think had got a bit lost in all the other demands of the job. (CH)

This theme illustrates how teachers move between the spaces of scientist, science teacher and researcher, and how teachers with different experiences of research can foster a love of inquiry and research through participation in science research projects, as well as a love of science and a sense that they themselves are scientists. One participant who developed a second career as a teacher after more than two decades as a nurse firmly stated that he did not see himself as a scientist. However, later into the interview, during a discussion about his experiences of research projects with his students, he said:

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> I have never really been involved in scientific research before, so it is kind of interesting from my viewpoint, being part, in a small way of a scientific project; if I am completely honest, I am doing science for the first time in my life, as opposed to teaching science. (MT)

Superordinate theme C: Collaboration

Collaboration and opportunities to develop new partnerships and networks by working with scientists, researchers, IRIS staff and teachers and students from other schools frequently featured as part of participants' experiences of research. The starting point for much discussion around participation was the recognition from participants that through research they found new ways to work with their students, with they and their students taking on different roles within this teaching and learning environment. Collaboration included teachers and students working together using software, equipment and research tools equally new to them both. This included using software to undertake genome annotation, selecting and implementing psychological questionnaires to measure well-being, using research level equipment from CERN to observe particle radiation and analysing calving rates of ice sheets from earth satellite observation images. Teachers and students also collaborated in communicating their research findings, through preparation for poster and oral presentations at conferences, school-based seminars and assemblies and visits to and by university-based researchers, which gave students opportunities to discuss their research findings and receive feedback.

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Participants described their role as distinct to their classroom-based teaching role, using a variety of terms, including ‘coach’, ‘advisor’, ‘team captain’ and ‘facilitator’. One participant vividly described how, when starting the research project, he invited the students to learn something new and challenging, with him as an equal collaborator:

> I showed them a screen shot of the software and said to them, “If that terrifies you, don’t worry, it terrifies me, I haven’t a clue what to do or how this works, but we can learn together”. (PW)

Another participant described her role with the students as that of an older sibling, with her main role being to encourage students to continue when they encountered challenge. One participant described how her role evolved during the project, from one that was a leadership role and had a didactic approach, to one where leadership and other roles were devolved to students:

> It is quite interesting to see how students work as teams and initially look to me as the team captain ... but in time … there will be certain people who would start to take on the leadership role and … then my role evolves from team captain to more of a cheerleader … (NR)

Participants recognised the different ways in which students worked together in the research environment, highlight mentoring within year groups and the role that older students played in encouraging and developing younger ones. For some teachers this near-peer mentoring was a central focus of the research project. For others, the peer-to-peer or near-peer mentoring was a positive consequence of running the research project with students, but not a

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direct goal or aim. For SG, the relationship with her academic established through the research project was 'integral' to the success of the project, and enabled her to support undergraduate scientists, further developing the research network:

> … the research experience would not have been anywhere near what it has turned out to be had it not had that integral link with an academic … I have felt able to support young scientists, their development, in a different way, I was able to support a third-year undergraduate student who … came and completed her third-year research project with us and she got a first for that. (SG)

For other participants who had not had face-to-face contact with an academic, contact by email with scientists and other teachers involved with the same research project was important in establishing collaborations between participants and other members of the research team:

> … emails with scientists, and with other teachers from different schools working on the research project have helped me connect with research through people outside of school and this has been positive. (JM)

Contact with members of the IRIS team (including the first author) was also noted as important for some participants in developing a collaboration. This supported the positive development of research projects through both drawing in the perspectives of other people and developing participants' sense of identity as scientists. In some cases, it was only through the experience of research projects that participants felt empowered to develop partnerships and networks with teachers from other schools to develop their capacity to teach science.

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Collaboration is a broad theme that involves students and teachers who have an already established professional relationship working in different ways and teachers working with academics, IRIS staff and other schools to form new networks and collaborations.

Superordinate theme D: Professional development

During the interviews, participants explored how their experience of research had been an opportunity for them to refresh their teaching of curriculum topics. Participants also reflected upon their own development as teachers, examining the different roles they had, additional skills they had developed and new pathways to professional development and recognition from colleagues. Recognition from colleagues was not wholly positive and this aspect revealed some of the tensions that participants felt and experienced when moving between the roles of science teacher and researcher.

At the outset of discussions around development, participants suggested that the opportunity to work in research with their students had 'refreshed' their teaching and that it was important to regularly take up opportunities to do this otherwise they could become 'stale':

> If you want to remain a good teacher you have to keep refreshing what you are doing, trying new things, reflecting, because otherwise you get stale, and if you get stale you get bored and you become boring and your lessons are very flat … I did a PhD … but my involvement was nothing to do with my former research background, my involvement is about exciting young people about biology and to do that you have to be excited yourself. (PW)

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GC also links his professional enthusiasm and excitement as a teacher with student engagement: '[research] keeps me enthusiastic, and of course that is going to spill off onto the kids'. Experience of research led other participants to reflect upon the different roles they have as a teacher, and how understanding these roles helped them respond to the needs of their students better.

Some participants took their understanding of how students learn during research and developed their teaching, most notably in the teaching of practical sessions and in more conceptually demanding curriculum content, such as radioactivity and genetics. NR suggested that it was only during her experience of research with students that she could see the struggles students had with experiments and stated that this challenged her to better understand student engagement in classroom practical sessions:

> Having seen how students have struggled with initial sort of practical troubleshooting in the research group time … It has really made me interrogate how I deliver practicals. (NR)

For GC, a teacher of over thirty years, using a detector that displayed alpha, beta and gamma particles on a computer screen had a significant impact in both the way he taught radioactivity and the ability of students to grasp an abstract concept in a 'visual' and 'real' (i.e. apparent to the senses) way that made it easier for them to understand. Making an abstract concept visible and therefore more comprehensible was also a feature of the development of biology A-level[2] teaching for two participants involve in the *Genome*

[2] Advanced-level examinations are taken by students at the end of Year 13, aged 17-18 years of age.

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Decoders research project. As with teaching radioactivity, incorporating research into the teaching of genetics enabled teachers to develop their pedagogy so that students were motivated to develop both knowledge and skills, and bring them together to develop a deeper understanding necessary to progress in the research project:

> The project has been hugely important for how I teach genetics, which is part of the A-level biology course as it gives the students the chance to learn abstract concepts in practical ways … they were able to connect aspects of their knowledge to the skills they had developed, and they were so enthused and motivated to keep going. (JM)

> This project is a fantastic tool for teaching, taking that very abstract idea [DNA], the students take it on board [in lessons] but it is not gripping in the way that the research is. (PW)

The responses of colleagues and managers was discussed by participants, with some identifying that their participation in research enhanced their colleagues' perception of their professionalism and abilities because they were creating additional opportunities for their students beyond the curriculum:

> I have noticed a shift with colleagues … other staff in the department, since I have been doing this research, they have seen me do something … that has a broader purpose and I feel that I am seen as more able, my abilities as scientist as well as a teacher have been recognised, I am seen as someone who is willing to develop extra

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> opportunities for students, to go above and beyond, and in a way that is unusual and perceived to be of high academic worth. (JM)

However, some participants reported tensions with colleagues who had different approaches to teaching:

> I try to be engaging and approachable about it, you know, try and get people to see my way of thinking but it is hard. Teachers can be a bit rigid in their thinking and their approaches, asking questions can be seen as a criticism and I don't understand that. Maybe that is the researcher in me, the scientist in me, I am constantly curious and that gets me into trouble sometimes, well no, not trouble, but it can be a bit tricky! (CI)

NR also identifies tensions that can occur between teaching colleagues when some are involved in research, with those teachers who are not research-active feeling inferior and worried about how they will be perceived in comparison to colleagues with research experience. NR suggests that for teachers to successfully integrate as part of the science community, there needs to be a positive, collaborative approach where teachers' perspectives are valued:

> I think one of the dangers of teachers being part of the science community is that … there are barriers to break down there, and [developing an] understanding that this is a process where we all want to work together, and we are not trying to reveal the imposter. (NR)

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Although participants describe some negative as well as positive reactions to their involvement in research with students, two participants who had been involved in research activities for more than three years identified leading research activities as a professional development opportunity that was an alternative to progression through management. SG suggests that having a family has been a barrier to her career progression and recognises that the full-time nature of management roles has prevented other women from progressing into leadership roles in schools. She suggests that research is a way of using the capacity and capabilities of 'really clever women', as research can be done in a part-time role and more flexibly than management and this would increase the quality and capacity of the teaching workforce. Participants described specific skills they had developed as part of their involvement in research. Practical skills included using high-quality microscopes and software. Soft skills included communication, reflection, confidence and self-belief.

Superordinate theme E: Student/societal development through research

Throughout the discussion of the previous four themes, participants often attribute their motivation to 'make time' for research projects to the students they teach. The networks and wider connections students forge through research are also recognised by participants as valuable. When participants discussed the contribution that working on a research project had made to the skills development of their students, communication skills and increased confidence were the most commonly identified and were seen as important development opportunities:

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> In terms of skills development, research projects are invaluable; students are finding the skills through experience of research, communication skills, teamwork, planning, leadership … and this increases their confidence and self-belief. (NR)

DG links the development of confidence and communication skills to the opportunities students have to forge networks through research that extend beyond their own school, so that students can share their experiences and findings with others and so better understand that the contribution that they have made is seen by others as valuable:

> Through research students have a chance to develop their communication skills and confidence … they can see that they have achieved something and that they need to share that with the outside world. (DG)

CI also suggests that the confidence students gain through research is something that moves with them into other educational spaces:

> I honestly believe that the students who do these projects feel better in other lessons and that the confidence they get is transferable. (CI)

JT describes how, for academically able students, sharing research with younger students gives them opportunities to develop communication skills that went beyond his own expectations of their abilities. CH identifies that students develop their evaluation skills through research and are more able to understand the quality of information they are presented with:

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> I think this research project has got them thinking about the quality of the science a little bit more. (CH)

CH suggests that through research projects students implicitly learn about careers in science that is therefore likely to have an impact upon their future choices:

> … with the research project they [the students] are experiencing something that is more like the reality of science and so they are getting a better understanding of what a career in science might be like, so we are not explicitly telling them, they are learning it for themselves and I think that ultimately that is a more powerful way. (CH)

PW and SG identified that some students value the opportunity to contribute to wider science research, and this is related to research projects providing students with the ability to forge wider connections through the contribution they make:

> [The students] also feel … that they are contributing to research, there are some of them that regard themselves as researchers having taking part in this project. (PW)

> The students are part of research community in school, and it was so important to be connected with researchers and make a contribution to that world. (SG)

As well as contributing to research, students were also motivated to participate in research projects if they made a connection with the real-life implications of the work and identified with the wider story:

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> One of the things that really appealed to the students was that this … has a narrative behind it with real life implications … because it was real they [the students] were prepared to sit down and work through the theory and relearn how to apply it. (PW)

CI described how students as a group repeatedly talked about how their work made a wider, positive contribution:

> The students develop such enthusiasm and confidence, in that they know what they have to do, and they know how to do it and they are able to explain it to people, what they are doing and why they are doing it and they have this little mantra, "because we are saving the world!". (CI)

SG saw research as a successful and positive way of connecting students to problems that impact their lives, now and in the future:

> Through research, students have become enthusiastic about biodiversity and have seen the real benefits that biodiversity brings them … it is that personal link, that tangible link that people have with biodiversity and research has created that link for the students … research can be a mechanism to develop a personal link with a subject for a student. (SG)

Although contributing to wider research and to solutions of larger problems are only mentioned by three participants, these are participants who have either been involved in research projects with students for more than three years (SG and CI) or have spent more time working on one research project in an intensive and sustained way over the course of

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one academic year (PW). This suggests that it may take time for students to recognise the contributions they are making to research and the wider world, but that this capacity to identify their contribution is possible and extremely valuable in developing confidence and self-belief and in growing and sustaining intrinsic motivation.

Discussion

Social identity approaches and teachers' professional identities

Social psychology and social identity approaches have much to offer when seeking to understand the experiences and professional identities of teachers, including the five 'I's: *Identification*, *Ideation*, *Interaction*, *Influence* and *Ideology*, identified by Haslam (2017). *Identification* is found in two themes that emerged from this study: (Re)Connection with science/research and Professional development. Indeed, teachers' social identities can be facilitated by the practices that we advocate in this study. Specifically, science teachers' participation in research projects gives them the opportunity to become members of a new group of scientists and/or researchers who are working together to better understand a research issue. This group membership is created both remotely, through email communication and interaction through IRIS' website and webinar facilities, and more immediately through attendance at workshops and conferences and visits with scientists, both at the participants' schools and at the scientists' places of work. This sense of group membership created through collaborative research shapes the pedagogy and teaching of the participants, as they bring their experiences of working with students in the context of research to their classroom-based teaching (themes Freedom to teach, Collaboration and Professional development). As a member of a community of scientists and researchers,

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participants felt able to develop new skills that were both practical (e.g. using new software and experimental techniques and laboratory equipment) and social-emotional (e.g. confidence, increased self-belief and self-worth). Being a member of the science and research community became incorporated into many of the participants' sense of self. This research suggests that research projects can provide teachers with group membership to the extent that this membership shapes their teaching approaches and behaviours and develops in them a sense of self that is both teacher and scientist.

In this study, *ideation* featured when teachers were identifying with the value of research and science as an aspect of their professional experience. Research gave participants the opportunity to develop a variety of teaching and learning methods and approaches, as they suggested that research projects gave them more opportunity to develop conceptual approaches and understanding in students (themes Freedom to teach and Professional development). This contrasted with the participants' experience of mainstream curriculum teaching, where the realities and practicalities of research were necessarily abbreviated. This created a tension for participants. Through science research, participants positively identified with their capacity to contribute to the development of their students, to furthering understanding and knowledge of scientific topics and potentially providing solutions to problems that impact the wider world (themes Freedom to teach, Professional development and Student/societal development through research contribution). This understanding of the nature of their identification, to long-term, ultimately altruistic goals might enable and encourage the design of teacher recruitment and retention schemes that reflect this motivation

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rather than the current focus on financial inducement and reward to address teacher shortages that are particularly acute in science subjects (Allen & Sims, 2017).

Key to the development of participants' group membership as scientists and/or researchers was their *interaction* or collaboration with scientists and researchers, students and teachers from other schools and IRIS staff. Through collaboration in active science research, participants were able to develop multi-faceted professional identities that incorporated aspects developed as part of their experience as scientists and researchers as well as newly developed and previously identified aspects of their role as teachers. These aspects of their teaching professional identities included that of collaborator with their student, mentor, coach, facilitator and supporter. Although participants recognised that the variety and flexibility of approaches to teaching and learning that they developed through research were sometimes in tension with their classroom-based methods, the new aspects of their professional identities did not detract from their identities as teachers but rather increased their own and typically their colleagues' perceptions of their professional self-worth. Jetten, Haslam and Haslam (2012) have identified the importance of multi-faceted professional identities and complex social networks in maintaining health and wellbeing. This current research supports this in the context of teacher professional identities and, again, could bring a helpful perspective to current understandings of how teachers could be encouraged and supported to remain in the profession.

In this study, *influence* emanated from a variety of players, with different power profiles, including students, school leaders, scientists and IRIS staff. Perhaps the greatest area of

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influence described by the participants was that from their students, with some participants directly attributing their initial and continuing participation in research as a response to their students' suggestions and even persistent requests. School leaders and colleagues also have the capacity to influence teachers' participation either through a positive recognition of the work or by not valuing it. For many participants the influence of the scientists they interacted with had a significant impact on their experience, generating increased feelings of professional worth and self-belief.

Towards a new model of professional identity: the 'teacher scientist'

This study has shown that research-active teachers develop a multi-faceted professional identity that includes teacher, scientist, researcher, collaborator and mentor. These different facets develop through their interactions with scientists, academics, other teachers and students. This article proposes the term 'teacher scientists' to describe the identity and role that these science teachers have. 'Teacher scientists' share five key elements:

- Regularly undertake research, grounded in the methods of science with their students, supported by scientific research partners
- Continually develop their subject knowledge through discussing current, peer-reviewed research with their students
- Develop and enhance their own practical skills and those of their students (e.g. using equipment, laboratory techniques, software) through training and engagement with research scientists
- Provide opportunities for students, scientists, teachers and technicians to establish networks through research that can include web-based communication (e.g. webinars,

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e-mail groups) and face-to-face interaction (e.g. conferences with student contributions, visits to university STEM departments, school-based seminars with visiting speakers)

- Encourage their students to disseminate their research at a range of levels including school assemblies, participation in external awards and competitions, presentation at conferences and publication in magazines and peer-reviewed journals.

One teacher described the elements of the 'teacher scientist' role in the following way:

> Working in research in this way is one of the most interesting, challenging and enjoyable things I have ever done in my professional life. I've been overwhelmed by the enthusiasm and commitment from the students … but I've also loved everything that I've learned myself about using Apollo … annotating a genome, working with research scientists and keeping my teaching and subject knowledge fresh. (JM)

This study has suggested that teacher scientists are able to develop a multi-faceted professional identity and more complex professional social networks, and that this contributes significantly to their sense of self-worth. Participants in this study did describe challenges of lack of time but were broadly positive about the experience. This may, in part, reflect a selection bias as other research-active teachers who had less positive experiences may have been reluctant to share them. Further research could try to capture these experiences so that the challenges of research and the barriers to becoming a teacher scientist are better understood. Participants also described research as providing them with a professional development alternative to management and said that this increased their sense of

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professional worth. This study drew on the experiences of teachers at a range of career stages and, unlike much previous research in this area, did not focus on a period of career development or transition. The range of levels of experience suggests that with support, science teachers are able to develop into teacher scientists at varied points in their career and do not seem to need threshold levels of teaching or research experience.

To further understanding of the concept of a teacher scientist as a model of effective continuing professional development it would be important to explore the perspectives of UK science teachers who do not participate in research, either because they choose not to or because they do not have the opportunity. The perspectives of students taught by research-active science teachers would also be valuable in understanding their experience of the collaborations and new ways of teaching and learning that are described by teachers in this study.

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Table 1. Subjects taught, teaching experience and current management roles of participants

	Main subject taught	**Number of years teaching experience**	**PhD**	**Management role**

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	Biology	Chemistry	Physics	1-5	6-11	12-17	18+	Mean		Yes
Female	2	2	4	2	3	0	3	12	4	2
Male	3	1	5	1	2	3	3	15	2	6
Total	**5**	**3**	**9**	**3**	**5**	**3**	**6**	**13.5**	**6**	**8**

Table 2. Geographical location and school type

School type	Academy	Local Authority Comprehensive	Local authority Grammar	Independent
Local Authority of school	South Lanarkshire, Cornwall	Bristol, Cornwall, Edinburgh, Kent, North Yorkshire, Sheffield x2, Stirling	Kent x3, North Yorkshire	Cornwall, Oxfordshire, Vale of the White Horse
Total number of schools	2	8	4	3

Table 3. Superordinate and sub-ordinate themes which emerged through a process of coding

Superordinate theme	**Subordinate themes**	**Codes**
	1) Flexible approach to teaching	Freedom, open-ended, new teaching methods, limited by time available,

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A) Freedom to teach	2) Variety of teaching and learning methods and approaches 3) Freedom from external exams and curriculum constraints	questions are open-ended, variety, discovery, traditional education vs new approaches.
B) (Re)Connection with science/research	1) Love and enjoyment of science in general and taught subject(s) 2) (Re)Connected with research through new equipment and/or subject content 3) (Re)Connected with role as a scientist	Enthusiasm, part of science community, thrilling, exciting, connected to researchers, described as a scientist, self-belief, new approach to subject, networks, refreshed.
C) Collaboration	1) Working with students in different and new ways to traditional student-teacher relationship 2) Working with scientists and researchers 3) Working with IRIS staff 4) Working with teachers and students from other schools	Capacity to contribute, reassurance from academic, integral link with academic, students as collaborators, peer-mentoring, near peer-mentoring, conferences and networking, support of IRIS staff, working beyond the school, partnerships, mentor, coach.
D) Professional development	1) Teaching and pedagogy 2) Recognition by colleagues in school 3) Research as a professional development opportunity, an alternative to management 4) Skills development – practical 5) Skills development – 'soft'	Acknowledgement, career progression, skill development, alternative to management, encouraging professional self, refreshing/enhancing teaching, making abstract concepts visible, specialist equipment used in teaching, stretch and challenge for staff and students, out of comfort zone.
E) Student/societal development through research	1) Development of students' skills and wider connections 2) Contribution to science and the world of research 3) Providing solutions to problems that impact the wider world	Real science, students enthused, students doing real research, practical skills, problem solving, independence, questioning, foundation for next research stage, supporting undergraduates, university choices, wider world relevance and importance, student presentation and communication skills, connecting with science/research, science in and for the community.

Table 4. Themes reflecting teachers' experience of being research active with their students

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Themes	**Number of references in interviews**
A: Freedom to teach	**97**
1. Flexible approach to teaching	34
2. Variety of teaching and learning methods and approaches	32
3. Freedom from external exams and curriculum constraints	31
B: (Re)Connection with science/research	**77**
1. Love and enjoyment of science in general and taught subject(s)	29
2. (Re)Connected with research through new equipment and/or subject content	27
3. (Re)Connected with role as a scientist	21
C: Collaboration	**74**
1. Working with students in different and new ways to traditional student-teacher relationship	26
2. Working with scientists and researchers	21
3. Working with IRIS staff	18
4. Working with teachers and students from other schools	9
D: Professional development	**70**
1. Teaching and pedagogy	18
2. Recognition by colleagues in school	15
3. Research as a professional development opportunity, an alternative to management	14
4. Skills development - practical	12
5. Skills development – ‘soft’	11
E: Student/societal development through research	**43**
1. Development of students’ skills and wider connections	20
2. Contribution to science and the world of research	13
3. Providing solutions to problems that impact the wider world	10

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